Implications of solar absorption data in the 3.3 and 3.6 µm region for remotely sensing ozone

JB Kumer, R Blatherwick and RB Chatfield

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Poster title: Implications of solar absorption data in the 3.3 and 3.6 µm region for remotely sensing ozone

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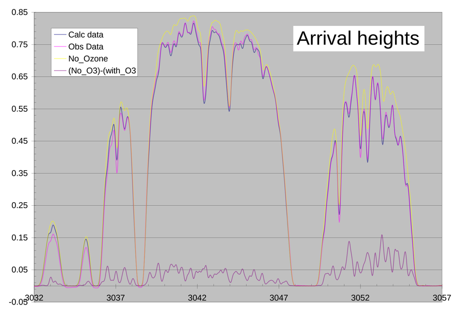
- The data were obtained by an FTS staring at the sun and were convolved to scaled VSWIR TIMS 0.18 cm^{-1} spectral resolution

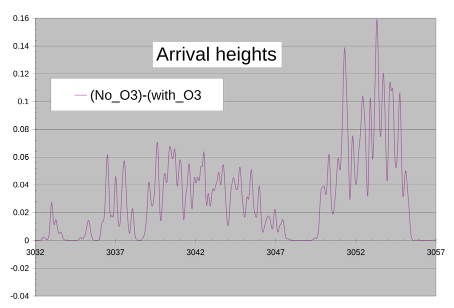
Characteristics of spectra collected & some preliminary modeling by Ron Blatherwick

place	time	Lat & lon	Solar zenith	Model multipliers		
				ozone	H2O	Any other
Arrival Heights	1836 UT 1840 UT	77.83 S 166.66 E	74.8 74.6	0.80 0.85	0.86 0.55	3.3 µm 3.6 µm
ARM	11:22 CDT 10:10 CDT	36.61 N 97.48 W	31.5 47.4			3.3 µm 3.6 µm
NCAR	10:02 MST 10:27 MST	40.03 N 105.24 W	62.8 60.5			3.3 µm 3.6 µm

- The arrival heights spectral transmittance data are modeled by adjusting model atmosphere species columns so as to minimize the RSS of the residuals
- Arrival Heights is at 200 m altitude. Data were recorded on Feb 01, 2000 (UT)
- (or at 0736 and 0740 local (NZD) on Feb. 02.)
- The ARM site is at 318 m altitude. Data were recorded on June 27, 1997 slide # 1
- The NCAR site is at 1625 m altitude. Data were recorded on Nov.12, 2008

- Ozone provides a very strong signal in this region, especially on the large wave# side
- All data shown in this set of slides is presented as convolved to $\Delta\nu = 0.18\ cm^{-1}$
- The ozone features have good spectral contrast at this resolution
- The actual VSWIR $\Delta\nu = 0.25\ cm^{-1}$ scales to 0.18 cm^{-1} on going from 2.3 to 3.3 µm



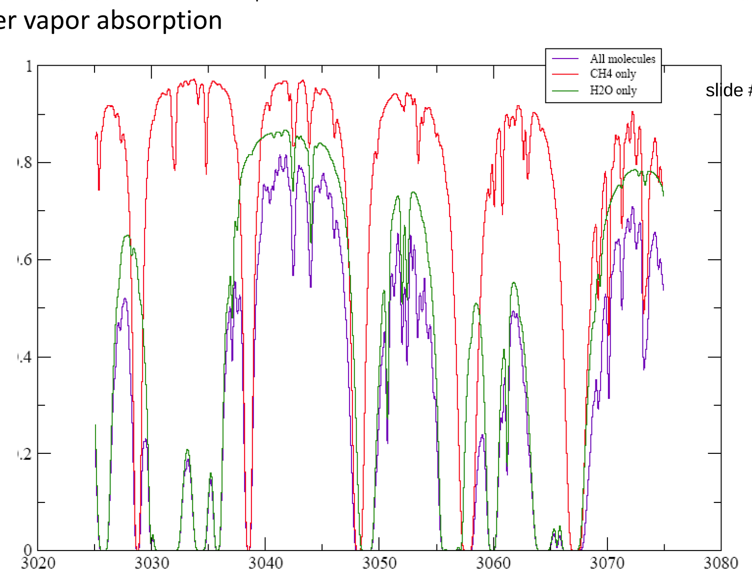


- Note the data & model (see left hand panel) agree well enough that the red trace of the data mostly overlies (buries) the black trace of the data
  - In slides below we'll examine the residuals to get an idea of how well the transmission of the ozone spectra through the water vapor is modeled
  - We'll examine the physics of the problem to determine where in the atmosphere the absorption by water is minimal and how it can be best handled
  - We'll investigate how the residuals can tell us when the water absorption is modeled to the limit that signal/noise and spectral parameters, etc, allow

slide # 2

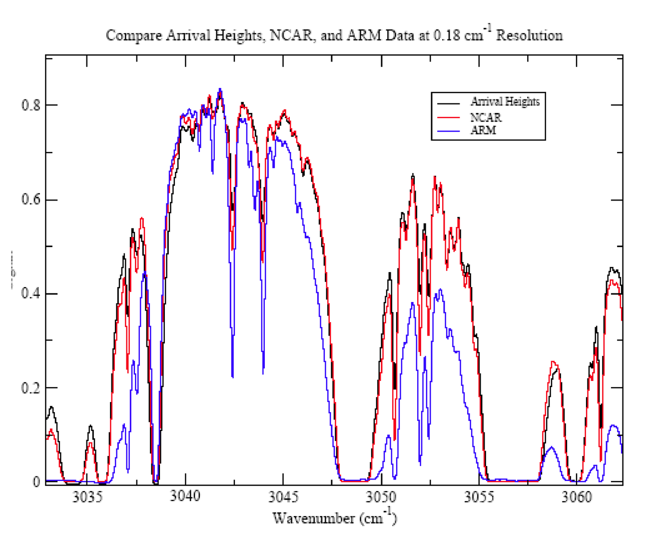
Absorption contributions of H_2O & CH_4 in the 3.3 µm region

- These are the strong absorbers in the region
- H_2O is hugely variable, CH_4 is not, this provides a handle on modeling the water vapor absorption

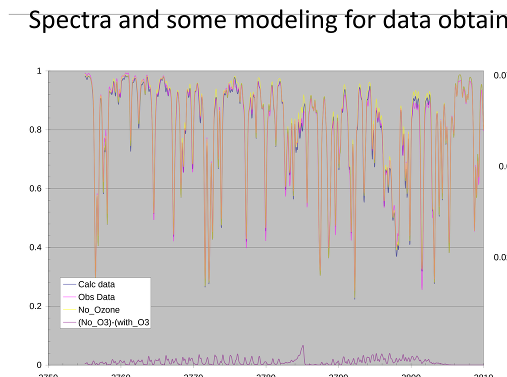


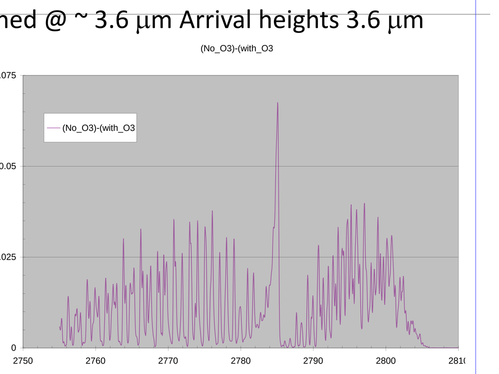
- Comparison ARM, Arrival heights & NCAR @ 3.3 µm
- ARM is wetter & at lower altitude (than NCAR) and with smaller solar zenith than @ NCAR
- NCAR & Arrival heights
- Note the ozone in the window feature @ 3033 to 3048 cm^{-1} in the wetter ARM data is remarkably similar to the other 2 cases except for the 2 weaker water lines near 3043 & 3044 cm^{-1}

slide # 4

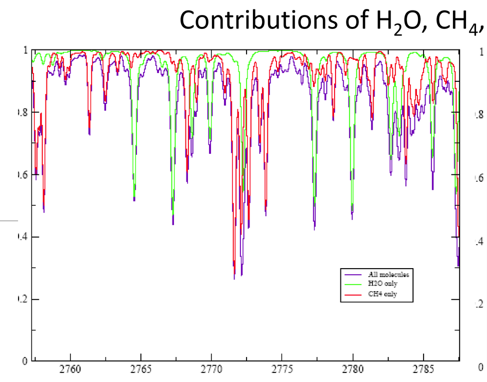


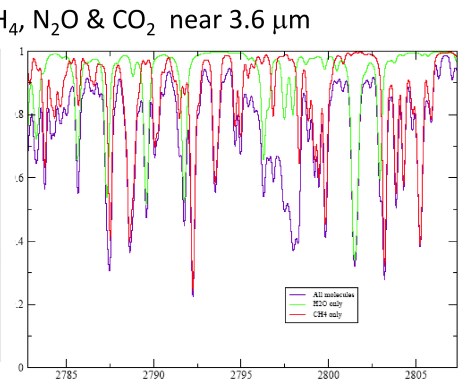
Spectra and some modeling for data obtained @ ~ 3.6 µm Arrival heights 3.6 µm

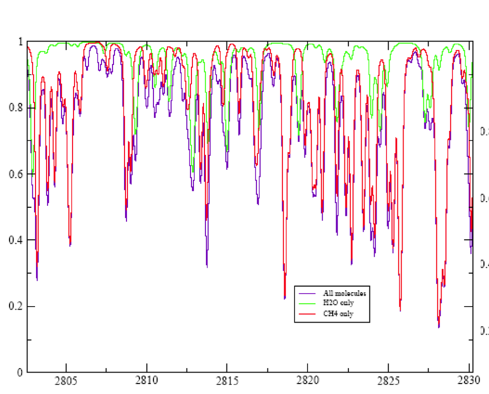


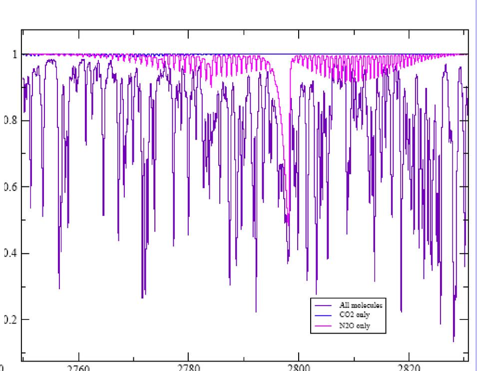


Contributions of H_2O, CH_4, N_2O & CO_2 near 3.6 µm









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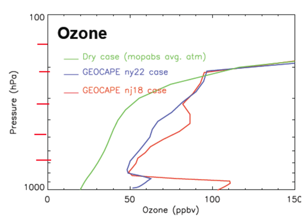
Conclusions

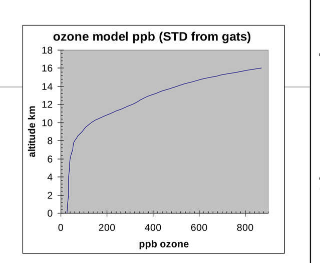
- We have investigated the problem posed by transmission of the ozone signal through the water vapor in the lower troposphere
  - The solar data indicates transmission through the Ozone Transmitting Water Windows (OTWW)can be modeled very well by fitting species columns that minimize residuals between the model and the data
  - This can be improved by adjusting the fit so that the mean values of the residuals are zero in the water window
  - Water vapor in only the first few km above the surface is important
    - An effect is the column multiplier that fits the transmission in OTWW will not necessarily be 1.0.
- 1% changes in H2O and in O3 produce changes in the observed spectral signature that have a marked orthogonality, therefore in principal, even the smallest ozone change can be measured given sufficient S/N

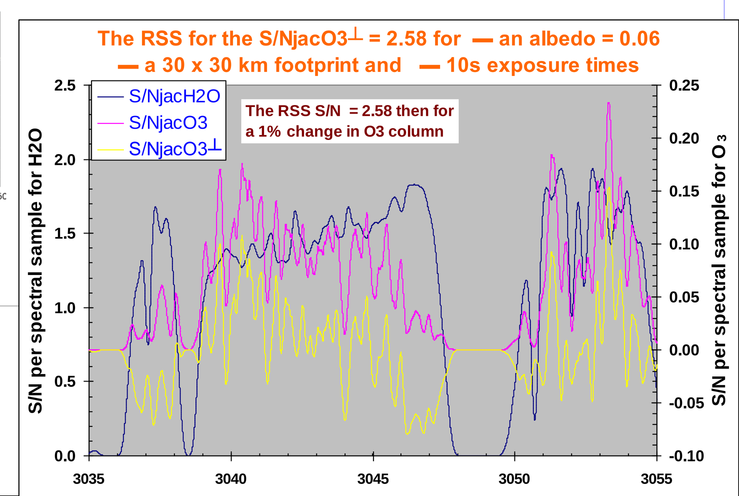
We conclude that the problem of transmission through the water is manageable

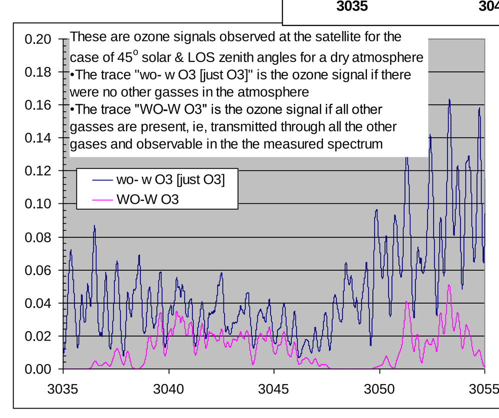
However there remain many problems that still require attention including but not limited to

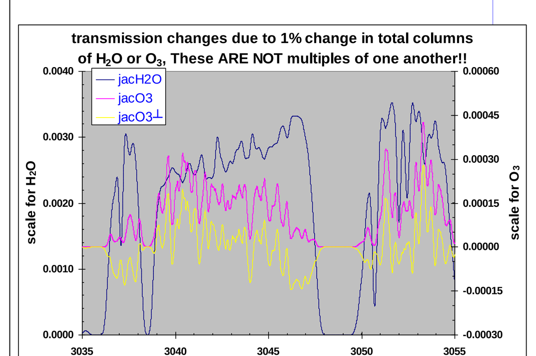
1. Simultaneous retrieval of albedo and surface emission
2. Spectral parameters
3. calibration

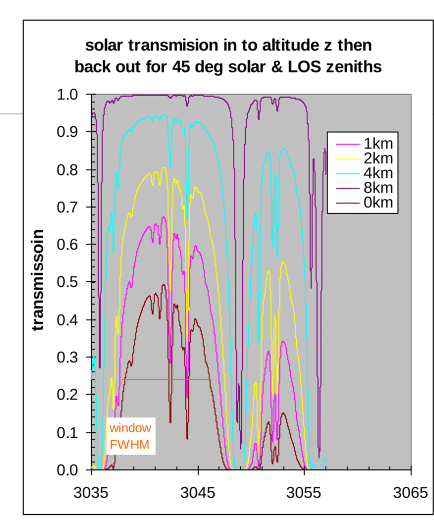


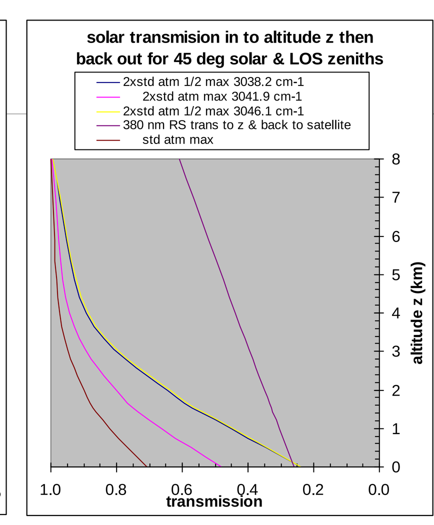


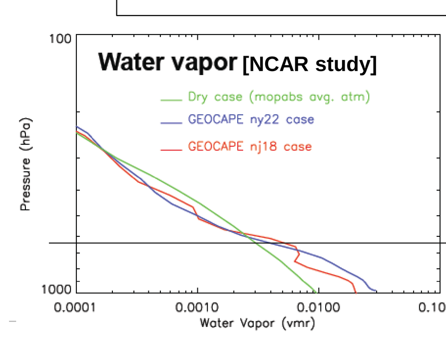


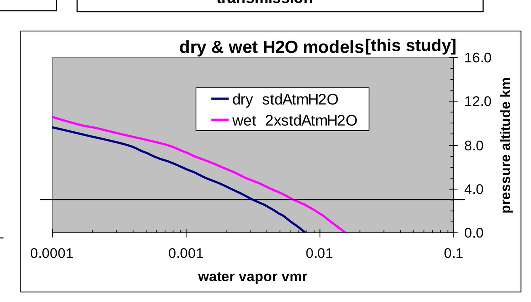






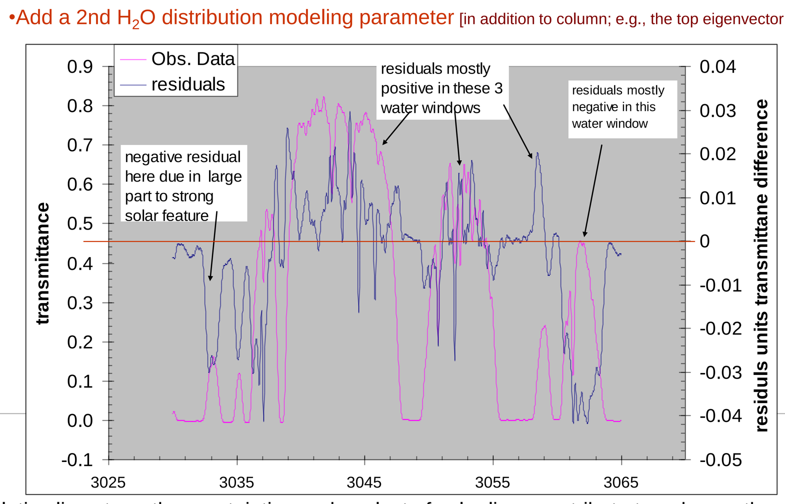






Modeling transmission through the water windows is necessary for retrieval of tropospheric ozone from the 3.3 µm data

- This modeling is first order successful if the mean of the residuals in the 2 **Ozone Transmission Windows** (**OTW**) on the region 3035 – 3056 cm^{-1} is ~ 0.
- For the unsophisticated modeling of this example [ie., retrieve species column multipliers that minimize residuals] the mean of all the residuals is about -0.44% [note solar lines were not included in model]
- the bias of residuals seen in ozone transmission windows from 3035 to 3057 cm^{-1} is balanced by the bias in the other direction in the windows near 3032, 3035 & 3062 cm^{-1}
  - limiting the modeling process to the OTW would considerably reduce the bias in that region
  - Add a 2nd H_2O distribution modeling parameter [in addition to column; e.g., the top eigenvector of the information matrix]



- Relative line strength uncertainties and neglect of solar lines contribute to enhance the standard deviation STDV of the residuals,
  - with directed spectroscopy studies the former can be mitigated and
  - the latter is trivial to eliminate

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find the component $f_{1\perp}$ *of* f_1

that is perpendicular to f_2

set $f_1 = a f_2 + f_{1\perp}$ *then calculate*

$$f_2 \cdot f_1 = a f_2 \cdot f_2; \quad a = f_2 \cdot f_1 / f_2 \cdot f_2$$

$$\Rightarrow f_{1\perp} = f_1 - (f_2 \cdot f_1 / f_2 \cdot f_2) f_2$$